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(71) Applicant
Baker Oil Tools Inc (USA-California),
500 City Parkway West, Orange, California 92668, United States of America

(72) Inventor
Douglas H. Fineberg

(74) Agent and/or Address for Service
Gill Jennings & Every,
53-64 Chancery Lane, London WC2A 1HN

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(56) Documents cited
GB A 2131069
GB A 2089398
GB 1476581
GB 1475929
GB 0941525

(58) Field of search
E1F

(54) Downhole flapper valve

(57) A flapper valve 10 has integral, oppositely projecting hinge pins 11 mounted in a recess 20a provided between two abutting tubular housing members 21 and 22. The flapper valve 10 is of cylindrical segment configuartion so as to maximise the opening within a conduit 1 in which it is mounted when the flapper valve is pivoted to its open position. The spring bias urging the flapper valve to the closed position is provided by helical springs mounted in surrounding relationship to the axis of the conduit and in an annular recess 20a provided between two abutting tubular housing members 21 and 22. The bottom surface 30a of the actuating sleeve 30 for the flapper is contoured so as to exert a minimum unbalanced torque on the flapper valve during opening with the mechanical opening force being balanced by an opposing force exerted by fluid pressure. Such construction permits a substantial reduction in the size of the hinge pins 11 and the space required to mount the pins and the helical springs, thus reducing the radial proportions of the flapper valve assemblage to increase the open bore diameter.

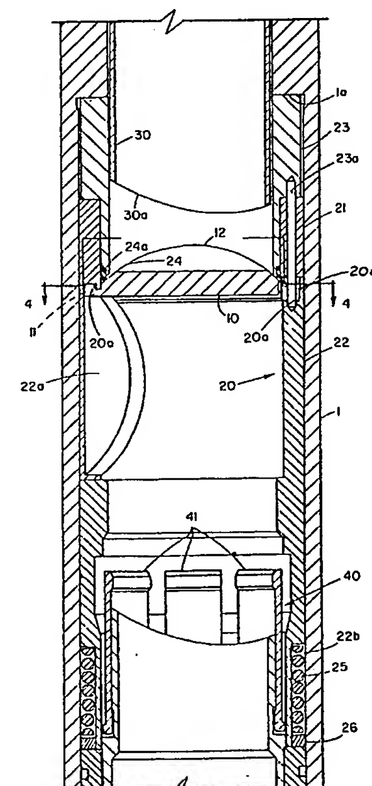

FIG.1

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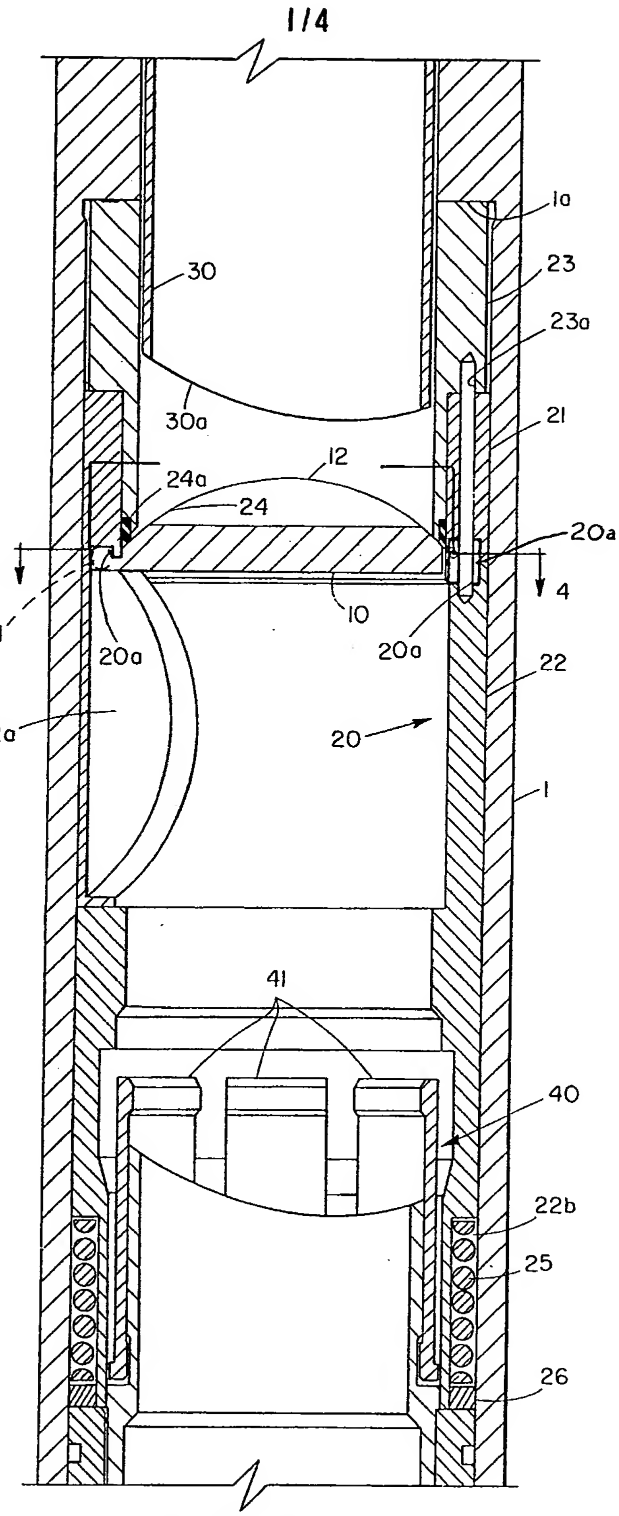

FIG.1

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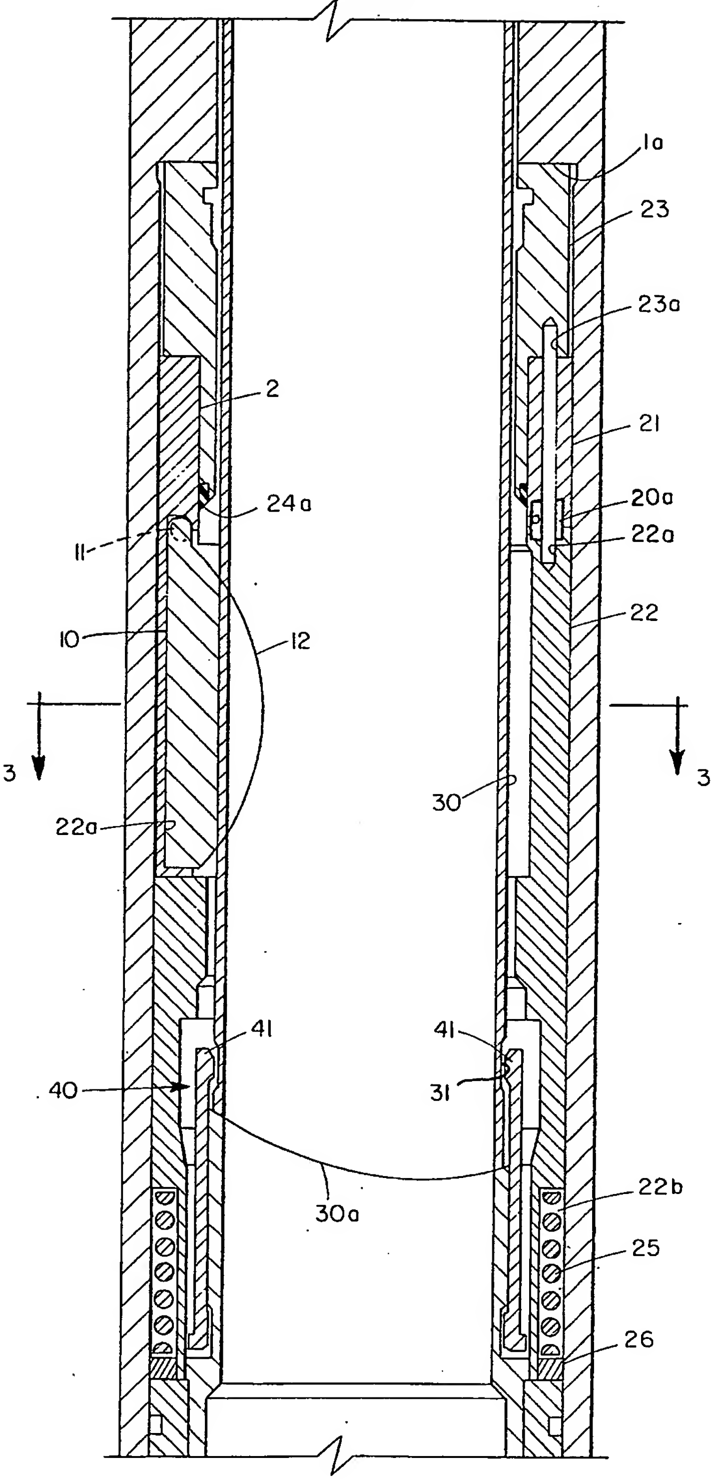

FIG.2

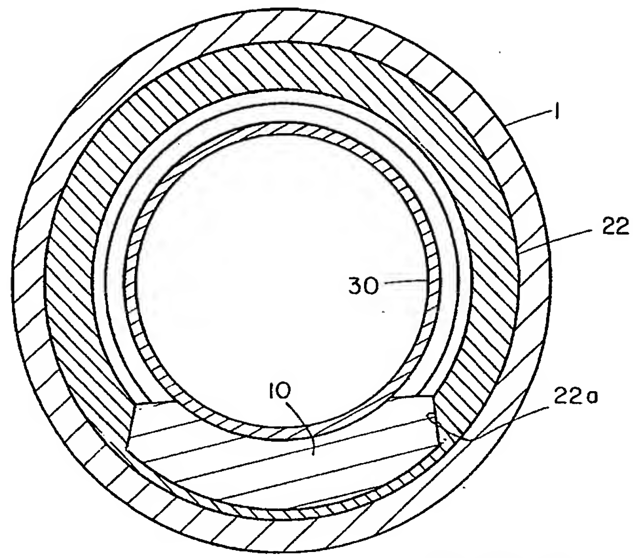

FIG.3

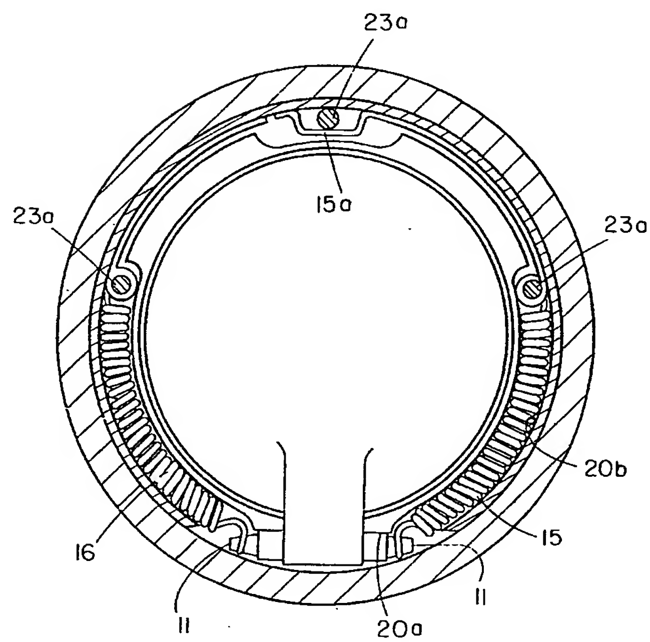

FIG.4

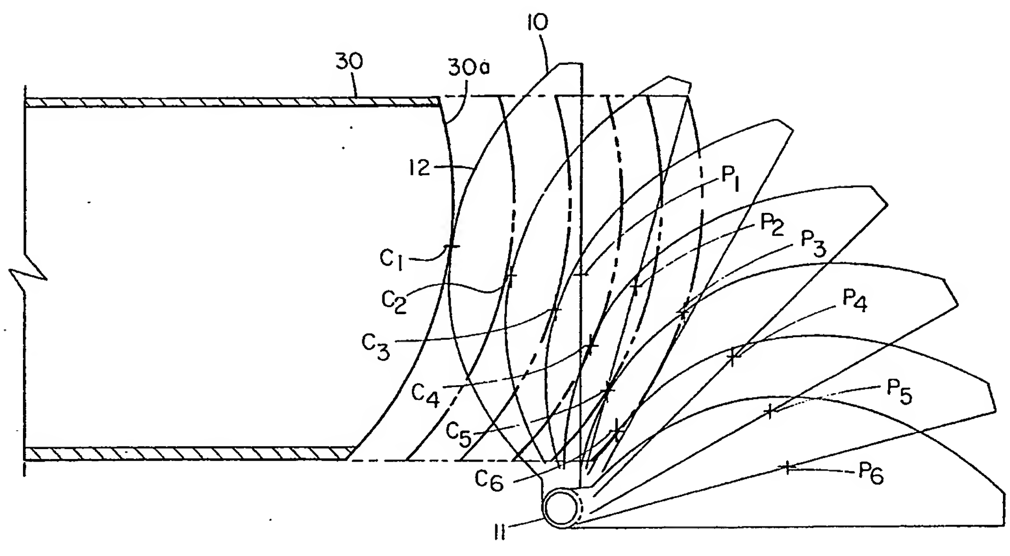

FIG.5

SPECIFICATION

Downhole flapper valve

This invention relates to a safety valve for subterranean wells and particularly to a flapper-type safety valve that is mounted in a downhole location.

Safety valves are often employed in subterranean wells. One common safety valve is a flapper-type valve which is pivotally mounted on an axis transverse to the longitudinal axis of the well bore and is spring urged to a horizontal transverse position where it engages a downwardly facing annular valve seating surface to close the well bore. Such flapper valves can then be shifted downwardly by an actuating sleeve to a substantially vertical open position wherein the flapper valve is disposed in a recess provided in the side wall of the particular well conduit or housing in which it is mounted.

To minimise the obstruction enlargement of the conduit required when the flapper valve is open, valves in the configuration of a cylindrical segment have been used, so that in the open position the downstream surfaces of the valve will be disposed adjacent the bore of the conduit, thus enlarging the flow area. See U.S. Patent Nos. 2,162,575 to Hacker and 2,447,842 to Cameron et at.

Obviously, the smaller the radial projection necessary for mounting the flapper, the greater will be the conduit bore, thus maximising the production capabilities of the particular conduit and faciitating the insertion of various tools therethrough.

In the normal subterranean oil or gas well, there is generally a substantial upwardly directed force produced on the upstream face of the flapper valve when it is disposed in its closed, transverse position with respect to the bore of the well conduit. The resultant pressure force is essentially centralised in the centre of the flapper valve. On the other hand, when the actuating sleeve is driven downwardly into abutting engagement with the upwardly facing or downstream face of the flapper valve, the point of engagement of such actuating sleeve with the flapper valve has heretofore been primarily a matter of chance. To facilitate the opening of the flapper valve, it has been previously proposed, as in said Hacker patent, that the elevated portions of the flapper valve be contacted by the actuating sleeve at a point more radially displaced from the pivot axis of the flapper valve than the resultant of the upward pressure force. While this makes the valve open more readily, it also imposes a substantial torque moment on the valve which must be absorbed by the hinge structure. As a result, hinge pins of fairly substantial diameter have heretofore been employed. The larger the diameter of the hinge pin, the larger the obstruction of that portion of the conduit housing within which the flapper valve is pivotally mounted.

It has also been common to employ conventional torsion springs for urging the flapper valve to its closed position. Such conventional springs generally embody a spring wire member having a plurality of coils wrapped around the hinge pin. Again, this inherently enlarges the required space for mounting the hinging elements of the flapper valve, thus further obstructing the conduit housing.

Minimisation of torque applied on the flapper valve hinge pin would permit reduction in the size of the hinge pin. Moreover, the elimination of the necessity for wrapping the coils of a torsion spring around the hinge pin would provide the opportunity for further reduction in the conduit obstruction due to the open flapper valve.

In the invention a valve for use in controlling flow in a fluid transmission conduit in a subterranean well comprises a valve flapper having upstream and downstream faces and being rotatable between open and closed positions for controlling the flow in the fluid transmission conduit; a flapper hinge about which the flapper rotates; a valve housing; a valve seat to hold pressure exerted on the upstream valve flapper face in the closed position; biasing means engaging the valve flapper and attached to the valve housing, the means being torsionally loaded as the valve flapper rotates from the closed to the open position to exert a restoring face for rotating the valve flapper to the closed position; and actuating means capable of rotatably shifting the valve flapper from the closed to the open position.

The invention provides a downhole flapper valve and actuator so constructed that the oppositely directed forces produced by the actuator and the downhole pressure when initially opening the valve are effectively applied at substantially the same radial distance from the hinge pin, thus minimising any torsional moment being applied to the flapper which must be absorbed by the hinge pin. This permits use of a smaller hinge pin since the stress that it must withstand has been significantly reduced. This invention also provides a flapper valve having a pair of oppositely projecting, co-axial hinge pins integrally formed thereon. In place of the conventional torsion spring employed as biasing means, optionally one but preferably, a pair of helical springs, extending circumferentially around at least a portion of the bore of the fluid transmission conduit, may be provided mounted in an appropriate recess in the housing defining the conduit. Such springs apply a torsional bias to the ends of the integral hinge pins to urge the flapper valve to its closed position.

This combination of preferred structural features reduces the obstruction of the conduit or, in other words, for a given maximum width of the housing containing the flapper valve, a greater conduit bore diameter can be accommodated.

The minimisation of the unbalanced torque operating on the flapper valve during its initial movement from a closed to an open position is accomplished in the preferred embodiment of the invention by shaping the downwardly facing surfaces of the actuating sleeve to cooperate with the upwardly facing cylindrical segment surfaces of the flapper valve body so that the effective point of application of the downward force produced by the actuating sleeve has a roughly equivalent moment arm at the resultant upward force produced by the

downhole fluid pressure.

In this preferred embodiment the valve flapper has the configuration of a transverse section of an annular cylindrical member defined by an intersecting cylindrical surface having an axis perpendicular to the axis of the cylindrical member, and the actuating means comprises an axially reciprocal tubular actuating member having an annular end face abutting the downstream face of the valve flapper such that upon movement of the actuating member in the upstream direction to exert a resultant upstream force on the valve flapper for opening the valve flapper, the surface of the annular end face being contoured for establishing, during rotation of the valve flapper to open position, changing contact points between the end face of the actuating member and the downstream valve face through which the upstream force exerted by the acuating member on the valve flapper remains in close radial alignment (with respect to the axis defined by the flapper hinge) with the resultant pressure force exerted on the valve flapper during initial rotation of the valve flapper about the flapper hinge between the closed and open positions. As the valve pivots to its open position, the points of contact of the actuating member with the flapper valve move inwardly toward the hinge axis and remain roughly equivalent to the moment arm of the resultant upwardly acting fluid pressure force. This means that during the opening of the flapper valve, the resultant moment produced on the flapper valve by the unbalanced actuating forces and fluid pressure forces is minimised and the difference in torque arms is small or non-existant so that the hinge pin experiences a minimum force resulting from the moment or force couple produced by the unbalanced forces. Preferably the radial separation of the resultant pressure force on the valve flapper from the flapper hinge is less than the radial separation of the upstream force exerted by the actuating member on the valve flapper from the flapper hinge. These preferred features may be attained by mating the surfaces of both the end face of the actuating member and downstream valve face arcuate. Generally the annular face of the actuating member engages the periphery of downstream face of the valve flapper.

In order that the flow area of the conduit is maximised, the configuration of the valve flapper is such that the axis of the annular cylindrical segment from which the valve flapper is formed is parallel to the fluid transmission conduit axis in the open position and the downstream surface of the valve flapper conforms to the exterior of the tubular actuating member.

The hinge generally comprises sometimes one but generally a pair of hinge pins, preferably attached to or formed integrally with the valve flapper.

The valve housing suitably comprises a downstream housing member, which comprises the valve seat, and an upstream housing member, the upstream and downstream housing members being in abutting relationship with a recess being defined therebetween; the flapper hinge pins are retained between the upstream and downstream housing members and traversing the recess. The biasing torsional springs are suitably disposed in the recess to provide the biasing force one end of each spring is secured to a hinge pin and the other end of each spring is secured within the recess, usually by an alignment pin for the two housing members, such that rotation of the valve flapper to the open position loads the springs in torsion.

One example of a valve according to the invention is illustrated in the accompanying drawings, in which:

Figure 1 is a vertical, sectional view of a flapper valve embodying this invention shown in its closed position relative to the well conduit in which it is mounted.

Figure 2 is a view similar to Figure 1 but illustrating a flapper valve in its open position relative to the conduit.

Figure 3 is a sectional view taken on the plane 3-3 of Figure 2.

Figure 4 is a sectional view taken on the plane 4-4 of Figure 1.

Figure 5 is a schematic view illustrating the loci of forces operable on the flapper valve.

Referring to Figure 1, a flapper valve assemblage embodying this invention is shown in assembled relationship within a well conduit 1. A flapper 10 is pivotally mounted for movement about a horizontal transverse axis by a pair of oppositely projecting, integral hinge pins 11 which are pivotally secured in an annular recess 20a defined between two axially adjacent tubular members 21 and 22 which cooperate to define a flapper valve housing 20. Locating pins 23a maintain the tubular members 21 and 22 in radial alignment.

The flapper valve housing 20 further comprises a valve seat sleeve 23 which is mounted in abutting relationship above the tubular elements 21 and 22 and is keyed thereto by the peripherally spaced locating pins 23a. The valve seat sleeve 23 defines at its bottom end an annular, cylindrically shaped sealing surface 24. An elastomeric seal 24a may be inserted in such surface. Sealing surface 24 corresponds to that generated by passing a cylindrical cutting element through the valve seat sleeve 23 along a path perpendicular to the axis of sleeve 23. A corresponding annular, cylindrically shaped seating surface 12 is formed on the flapper 10, which corresponds to the shape of a circular segment cut from an annular cylindrical member by passing a cutting cylinder through the annular cylindrical member along a radial axis perpendicular to the axis of the cylindrical member. As a result, when the flapper 10 is pivoted about hinge pins 11 to its substantially vertical, open position shown in Figure 2, the internal contour of the flapper 10 will correspond to the cylindrical bore of the valve seat defining sleeve 23, and hence provide unrestricted fluid passage through such bore. A generally circular, radial recess 22a is provided in the side wall of the lower tubular member 22 to receive the main body portion of the flapper valve 10 within such recess when the flapper valve 10 is pivoted to its vertical position as shown in Figure 2.

The flapper 10 is shifted from its horizontal closed position to its substantially vertical open position by the downward movement of an actuating sleeve 30 which is conventionally mounted in the bore of conduit 1, and is moved downwardly by a conventional fluid pressure actuating device (not shown). For example, the actuating mechanism provided in co-pending application, Serial No. 280,592 filed July 6, 1981, may be utilised for effecting the operation of the actuating sleeve 30. If desired, a conventional latch mechanism 40 comprising a plurality of latching collet arms 41 may be mounted within the interior of the lower tubular member 22 to engage an annular recess 31 in the actuating sleeve 30 in latching relationship when it is moved downwardly to its valve opening position, as illustrated in Figure 2. Such latching mechanism is entirely conventional and forms no part of the instant invention.

Referring now to Figure 4, it was previously mentioned that the hinge pins 11 are integrally formed with the body of the flapper 10. The size of hinge pins 11 is less than that of conventional hinge pin assemblies used with conventional assemblies. The integral hinge pins 11 are received within an annular recess 20a. The recess 20a extends annularly around the entire abutting surfaces of the tubular members 21 and 22 and provides space for mounting a pair of helical torsion springs 15 and 16, which extend circumferentially around a portion of the valve housing.

Each spring has one end thereof inserted in a transverse aperture (not shown) provided in one integral hinge pin 11. The other ends of the springs 15 and 16 are first wrapped around the axially extending alignment pins 23a, which are mounted between the tubular members 20 and 21 and valve seat sleeve 23, and the ends extend around the remainder of the annular recess 20a. The one spring 15 may be provided with a radially inwardly bent portion 15a to extend around a locating pin 23a. This prevents inadvertent reverse assembly of springs 15 and 16. In any event it will be apparent to those skilled in the art that the helical springs 15 and 16 are in torsion relative to the flapper 10 so that the pivotal movement of flapper 10 from its horizontal closed position shown in Figure 1 to its vertical open position shown in Figure 2 is opposed by a spring bias produced by the torsionally winding of the helical springs 15 and 16. Thus, the flapper 10 is normally biased to its closed position shown in Figure 1 and will return to such position whenever permitted by the upward withdrawal of the actuating sleeve 30.

As it is known to those skilled in the art, the flapper 10 may be moved to its open position by providing the actuating sleeve 30 with an end face of generally radial configuration. In accordance with this invention, the end face 30a of the actuating sleeve 30 is preferably arcuately formed as viewed in a vertical plane so as to initially contact the inner portions of the annular cylindrical seating surface 12 of flapper 10 at a position which is just slightly radially spaced beyond the axis of the conduit 1 relative to the axis of the hinge pins 11. The resultant force exerted on the flapper 10 by fluid pressure existing below the flapper valve normally acts on the flapper 10 at a position corresponding to the axis of the conduit.

The radial position of such points are clearly indicated by the geometric drawing of Figure 5, wherein the successive points C1, C2.....C6, indicate the locus of the path of contact of the curved bottom surface 30a of the actuating sleeve 30 with the inner portion of the upwardly facing annular seating surface 12 of the flapper 10. These points represent the effective point of application of downward force to the flapper 10 by the actuating sleeve 30. Similarly, the points P1, P2....P6, represent the effective point of application of the resultant fluid pressure forces exerted in an upward direction on the flapper 10 as it moves from its horizontal closed position to its substantially vertical open position. Point C1 in turn corresponds to point P1. Similarly points 2 through 6 correspond.

It will be noted that the radial distance from the axis of the pivot pins 11 to the initial contact point C, is slightly greater than, but roughly equal to, the radial distance from the axis of hinge pins 11 to the point P1 of application of the resultant fluid pressure force. Thus, the downward force on the acutating sleeve 33 need only be approximately equal to the upward pressure force on the flapper 10 and flapper 10 when the flapper valve begins to open. In the preferred embodiment depicted herein, the radius of the contact points C1, C2....C6 are agressively closer to the axis of hinge pins 11 than the locus of the point P1, P2....P6 representing the location of the resultant fluid pressure force. Thus, the forces on the flapper 10 produced by the downward force exerted by actuating sleeve 30 in opposition to the upward fluid pressure forces will initially exert only a slight moment on the flapper 10, thus minimising the twisting force exerted on the hinge pins 11 and permitting such pins to be of a substantially smaller diameter, on the order of 50 percent of the hinge pin diameter normally provided for the same size, conventional flapper valve. Moreover, as the opening movement of the flapper 10 progresses, the moment arm of the fluid pressure forces represented by these points P1, P2.....P6 remains approximately equal to the moment arm of the opening forces represented by points C1, C2....C6 because the fluid pressure force is always upwardly directed and only slight component of such force will actually be effectively operating on the partially open flapper valve. Therefore, no significant resultant torque is applied to the hinge pins.

Actuating sleeve 30 must, of course, be suitably keyed to the tubular housing 20 to maintain the curved bottom contact surface 30a in the desired angular relation to the flapper 10 thoughout the downward movement of sleeve 30.

From the foregoing description, it is apparent that the described construction permits the absolute minimisation of the space required for effecting the pivotal mounting of the flapper 10 and the imposition of a torasional bias to such flapper. Morever, the substantial balancing of the contact

forces exerted by the actuating sleeve 30 and effective moment arms with the resultant fluid pressure forces operating on the upstream face of the flapper valve 10 effects a minimum application of unbalanced torque to the flapper valve which must be absorbed by the pivot pins, thus permitting the diameter of such pivot pins to be significantly smaller than the pin diameters previously employed. Lastly, the fabrication of the pivot pins 11 is an integral part of the body of the flapper 10 inherently results in a stronger construction than the separate pins heretofore employed.

It will be understood by those skilled in the art that both a curved flow tube and a curved flapper are not essentially related to the position of the spring utilised herein. The spring can be employed with a more conventional flow tube and flapper valve configuration. Furthermore, the curved flapper valve configuration, and annular torsion spring, can be employed with a flow tube having a flat end and still achieve a significant increase in flow area.

CLAIMS

1. A valve for use in controlling flow in a fluid transmission conduit in a substerranean well which comprises:

a valve flapper having upsteam and downstream faces and being rotatable between open and closed positions for controlling the flow in the fluid transmission conduit;

a flapper hinge about which the flapper rotates;

a valve housing;

a valve seat to hold pressure exerted on the upstream valve flapper face in the closed position;

biasing means engaging the valve flapper and attached to the valve housing, the means being torsionally loaded as the valve flapper rotates from the closed to the open position to exert a restoring force for rotating the valve flapper to the closed position; and

actuating means capable of rotatably shifting the valve flapper from the closed to the open position.

2. A valve according to claim 1 in which the valve flapper has the configuration of a transverse section of an annular cylindrical member defined by an intersecting cylindrical surface having an axis perpendicular to the axis of the cylindrical member, and the actuating means comprises an axially reciprocal tubular actuating member having an annular end face abutting the downstream face of the valve flapper upon movement of the actuating member in the upstream direction to exert a resultant upstream force on the valve flapper for opening the valve flapper, the surface of the annular end face and of the downstream valve face being contoured for establishing, during rotation of the valve flapper to open position, changing contact points between the end face of the actuating member and the downstream valve face through which the upstream force exerted by the actuating member on the valve flapper remains in close radial alignment with the resultant pressure force exerted on the valve flapper during initial rotation of the valve flapper about the flapper hinge between the closed and open positions, whereby the couple created by the oppositely directed upstream force exerted by the actuating member on the valve flapper and by the resultant pressure force is minimised to reduce bending and shear on the flapper hinge.

3. A valve according to claim 2 wherein the radial separation of the resultant pressure force on the valve flapper from the flapper hinge is less than the radial separation of the upstream force exerted by the actuating member on the valve flapper from the flapper hinge.

4. A valve according to claim 2 wherein the contoured surface on the actuating member and the downstream valve face comprise arcuate surfaces respectively formed on the annular end face and the downstream valve face.

5. A valve according to any one of claims 1 to 4 in which the biasing means comprises at least one torsionally loaded spring extending circumferentially around at least a portion of the bore of the fluid transmission conduit.

6. A valve according to any one of claims 1 to 5 wherein the flapper hinge comprises a pair of coaxial integral hinge pins formed on said valve flapper.

7. A valve according to claim 6 in which the valve housing comprises a downstream housing member, which comprises the valve seat, and an upstream housing member, the upstream and downstream housing members being in abutting relationship with a recess being defined therebetween and extending peripherally around the valve housing; the flapper hinge pins are retained between the upstream and downstream housing members and traversing the recess.

8. A valve according to claim 7 wherein the recess extends peripherally around the valve housing and the biasing means comprises at least one torsional spring disposed in the recess.

9. A valve according to claim 8 wherein the housing means comprises a pair of coil springs each having one end secured to one of the hinge pins and in which rotation of the valve flapper about the axis of rotation to open the flapper loads said springs in torsion.

10. A valve according to any one of claims 6 to 9 wherein said hinge pins are integral with the valve flapper.

11. A valve according to any preceding claim in which the annular end face engages the periphery of the downstream face of the valve flapper.

12. A valve according to any preceding claim further comprising means for maintaining angular alignment between the tubular actuating member and the valve flapper about the axis of the fluid transmission conduit.

13. A valve according to any preceding claim wherein the axis of the annular cylindrical segment from which the valve flapper is formed is parallel to the fluid transmission conduit axis when the valve flapper is fully open.

14. A valve according to any preceding claim in which the valve flapper configuration confirms to

the exterior of the tubular actuating member when the valve flapper is open to increase the effective size of the valve housing bore relative to the outer diameter of the valve housing.

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